I YEAR BE (II SEM)

ENGINEERING PHYSICS II (SUB CODE: PH6251)

UNIT I - CONDUCTING MATERIALS
PART – A

1. What are the special features of free electron theory of metals?

The classical free electron theory visualizes a metal as an array atoms (icons) premeated by a gas of free electrons. There is no mutual interaction among the free electrons or between ions & electrons. The free electrons can move freely in random directions under the constant potential provided by the fixed ions of the lattice.

2. What are failures of classical free electron theory?

   i. It predicated that the value of electronic specific heat as 3/2 R. But experimentally it is about 0.01R only.
   ii. The ratio between thermal conductivity and electrical conductivity is not constant at low temperatures.
   iii. The theoretical value of paramagnetic susceptibility is greater than the experimental value.
   iv. The electrical conductivity of semiconductors, ferromagnetism, the photoelectric effect and black body radiation cannot be explained.

3. What are the important applications of quantum free electron theory?

Here the wave aspect of electrons is taken into account. Particularly the fermi level electrons are responsible for electrical conductivity and thermal conductivity. Hence the correct values of electrical and thermal conductivities and electronic specific heat are obtained.

4. Give the meaning of wave function?

The wave function is defined as the probability amplitude of a particle to find its location in the atomic structure and measures the variations of matter waves associated with the particles. It is the complex displacement of the matter waves.

Further the probability density $|\Psi^*\Psi|$ is the real quantity and it tells us where the particle is likely to be not where it is. Thus it connects the particle and its associated wave statistically.

5. What is fermi energy? What is its importance?

Fermi energy is the maximum energy of the filled energy stables in a metal at 0 K. It depends on the free electron density. The properties of metals depend on the value of fermi energy since the effective electrons taking part in various physical phenomena or processes are only the fermi level electrons.

6. Define density of states. What is its use?

Density of states is defined as the number of energy states per unit volume in an energy interval. It is used to calculate the number of charge carriers per unit volume of the solid.

7. Define band gap, valence band & conduction band?

Band gap is the energy difference between the minimum energy of conduction band and the maximum energy of valence band. Those energies lying in the band gap are not allowed to occupy by the electrons of that solid.

Valence band is the region of energy levels where the valence electrons occupy their positions.

Conduction band is the region of energy levels where the conduction electrons or free electrons occupy their positions.

8. What are holes?

Holes are the vacant sites in the valence band of a solid. These will behave like positive charge carriers having the mass of electron in the presence of applied electric field.

9. Define effective mass of electron.

Effective mass of electron. ‘m*’ is the mass of the electron when its moving through the periodic lattice.

For example, in copper m*> m where m is the rest mass of an electron.

10. State the relation between thermal conductivity and electrical conductivity. Does it hold good for all types of materials.

$K / \sigma = LT$ where L is a constant called Lorentz number and T is the temperature of metal in Kelvin. This relation is hold only for metals. At low temperatures this relation is not true even for metals.

10. Explain thermal conductivity.

Thermal conductivity of a material 'K' is equal to the amount of heat flowing power unit through the material having unit area of cross section and maintaining a unit temperature gradient. In general the total thermal conductivity of a solid is the sum of thermal conductivity due to free electrons and thermal conductivity due to photons (lattice vibrations)

i.e., $K_{total} = K_{electron} + K_{photon}$

In metals, $K_{electron} >> K_{photon}$

In non-metallic conductors, K_{photon} is a dominating one.

Example: Diamond at 30 K is a better thermal conductor than silver at 30 K.

But in insulators, $K_{total} = K_{photon}$.

The thermal conductivity of a metal increase exponentially from 0 K to 20 K and then decreases with increase of temperature.

11. What are the sources of electrical resistance in metals?

i) Lattice defects and ii) thermal vibrations of the lattice.

When the electron is moving through a perfect periodic lattice, there is no resistivity except temperature dependent resistivity. The impurities and residual defects produce so many scattering centers and reduce the mean free path of electrons. Similarly if the vibration amplitude increases with the increase of temperature, the mean free path of electron decreases. Hence the resistivity increases.

12. Give the microscopic form of ohm's law in a metallic conductor. Whether the ohm's law is true at all temperatures?

$J = \sigma E$

Where J is the current density, σ is the electrical conductivity and E is the electric field intensity.

The ohm's law is not true at all temperatures in a conductor, since the resistance of a conductor varies with temperature in a complicated manner at different range of temperatures.

13. Define drift velocity? How is it different from thermal velocity of an electron?

The drift velocity is defined as the average velocity acquired by an electron in the presence of an electric field $V_d = J / ne$

The thermal velocity is random in nature and is very high (10^5 m/s). But the drift velocity i_d directional one and is very small (50 cm/s).

14. Define relaxation and collision time of free electrons in a metal.

Relaxation time is defined as the time taken by an electron to reach equilibrium position from its disturbed position in the presence of electric field. The collision time is defined as the average time taken by an electron between two successive collisions. For an isotropic collision, the relaxation time and collision time are equal.

15.Distinguish between conductor and semiconductor on the basis their electrical conductivity.

Conductor has electrical conductivity of 10^4 to 10^9 $ohm^{-1}m^{-1}$ and semiconductor has electrical conductivity of 10^3 to 10^4 $ohm^{-1}m^{-1}$. For conductors, the electrical conductivity is decreased with respect to addition impurities and increase of temperature due to decrease in mean free path. But in semiconductors, the electrical conductivity is increased with respect to addition of impurities and increase of temperature due to increase of charge density.

16. Aluminium has three valence electrons and copper has one valence electron. Why do we have large electrical conductivity for copper than Aluminium?

Based on quantum electron theory, even though aluminium has three times as many conduction electrons as copper, the area of the fermi surface in aluminium is about the same in copper. But the number of uncompensated electrons in the fermi surface of copper is more than the number of uncompensated electrons in the fermi surface of aluminium.since the value of the electrical conductivity depends on the number of compensated electrons, copper has higher electrical conductivity than aluminium.

17. State Widemann – Franz law.

The ratio between thermal conductivity and electrical conductivity of a metal is a constant at a given temperature.

i.e., $K / \sigma T = L$ (constant)

Where K and σ are thermal conductivity and electrical conductivity respectively.

UNIT – II SEMI CONDUCTING MATERIALS
PART – A

1.What are the p-type and n-type semi conductors?

P-type semi conductor is the one having holes as the majority charge carriers and electrons as the minority charge carriers.
Example: Silicon or Germanium doped with trivalent impurities like Al, Ga and In.
N-type semi conductor is the one having electrons as the majority charge carriers and holes as the minority charge carriers.
Example: Silicon or Germanium doped with pentavalent impurities like P, As and Sb.

14. What are donors and acceptors?

The donors are the doped pentavalent impurity atoms like P, As and Sb in Silicon or Germanium donating an electron from its atom to Silicon or Germanium crystal. The acceptors are the doped trivalent impurity atoms like Al, Ga and In in Silicon or Germanium accepting an electron from each Silicon or Germanium atom.

3.Why do we prefer extrinsic semi conductors than intrinsic semi conductors?

Extrinsic semi conductors have high electrical conductivity which depends on the number of dopant (impurity) atoms and have high operating temperature. But in the intrinsic semi conductors the electrical conductivity is very small and is not a constant at different temperatures.

4. What is the meaning of bandgap of a semi conductor?

Bandgap (or) energy gap of a semi conductor is the region of energies, which are not allowed to occupy by the electron of that material. Its equal to the energy difference between the minimum energy of conduction band and the maximum energy of valence band of that material. But in a band gap the added impurity atoms can have their energy levels.

5.Distinguish between direct bandgap and indirect semiconductors.

In direct bandgap semiconductors the electron from the conduction band can directly recombine with the hole in the valence band emitting a light photon and the charge carriers have smaller lifetime. Examples: GaAs, InP. But in indirect bandgap semiconductors, the electron from the conduction band can recombine with a hole in the valence band in an indirect manner through the traps. The lifetime of charge carriers is more. Examples: Si, Ge.

6. What is fermi level in a semiconductor?

Fermi level in a semiconductor is the energy level situated in the bandgap of the semiconductor. It is exactly located at the middle of the bandgap in the case of intrinsic semiconductor. Thus it is a reference energy level from which the maximum energy the valence band and minimum energy of the conduction band are referred. In extrinsic semiconductors, the fermi level is situated in between the acceptor energy level and maximum energy of the valence band in the case of p-type semiconductor and is situated in between the donor energy level and minimum energy of the conduction band in the case of n-type semiconductor.

7. Discuss the variation of fermi level with temperature in the case of p-type semiconductor or n-type semiconductor.

The fermi level in extrinsic semiconductor shifts down in the n-type and shifts up in the p-type and reaches the middle of the bandgap when the temperature is gradually increased up to 500 K.

8. Define the operating temperature of a semiconductor.

The operating temperature of a semiconductor is defined as the maximum temperature up to which extrinsic behavior or amplification is existed. For example, silicon has the operating temperature of 200°C so that the silicon transistors or diodes can be operated safely with effect of doped impurities upto 200°C.

9. Why do we prefer silicon for transistors and GaAs for laser diodes?

Silicon is an indirect bandgap semiconductor and so the lifetime of the charge carriers are more and hence amplifications are more.
GaAs is the direct bandgap semiconductor and the electrons can recombine directly with the holes in the valence band emitting a light photon.

10. What is Hall effect? What is its use in the semiconductors?

Hall effect to the creation of a transverse e.m.f. across the semiconductor slab carrying current in the perpendicular magnetic field. Using this effect the concentration and the sign of charge can be determined. Further the mobility of charge carriers can also be determined.

11. What is the effect of doped impurities and increase of temperature in a semiconductor?

The doped impurities and increase of temperature create the charge carriers and thereby increasing the electrical conductivity of a semiconductor, eventhough there is an increase of scattering centers. Since the increase of conductivity due to doped impurities and increase of temperature is larger than the reduction of conductivity due to increase of scattering centers.

UNIT – III MAGNETIC AND SUPERCONDUCTING MATERIALS
PART – A

1. What are the essential differences between hard and soft magnetic materials?

Sl.No.	Hard magnetic material	Soft magnetic material
i.	It has large area hysteresis Loop.	It has smaller area hysteresis loop
ii.	It has high coercivity and high retentivity.	It has less coercivity and lesser retentivity.
iii.	It has irreversible domain wall movement.	It has reversible domain wall movement.
iv.	It has lesser permeability.	It has large permeability.
v.	It is used for making permanent magnets.	It is used for making electromagnets.

2. Explain the terms remenance and corecivity.

Remenance is the property of the magnetic material by which it retains some magnetization when the magnetizing field is reduced to zero. It is expressed in terms of weber/m^2. Coercivity is the property of the magnetic material by which it requires a demagnetizing force to destroy the residual magnetism in it. It is expressed in terms of ampere turn/m.

15. Name two uses of soft magnetic materials.

i. Since soft magnetic materials can be easily magnetized or demagnetized, these are used to make electromagnets used in cranes.
ii. Due to their low hysteresis loss, they are also used as transformer core materials.

4.What are the requirements of transformer core material?

Transformer core material should have high resistivity to reduce eddy current losses and magnetically soft to reduce hysteresis losses.

5. What are magnetostriction materials?

Magnetic materials whose length along the axis magnetization may charge when it is placed parallel to the magnetic field are called magnetostriction materials. These are used to produce ultrasonic waves and deign mechanical filters used in the single side band transmission of ratio waves.

6. Give the origin of magnetic moment in magnetic materials.

The magnetic moment originates from the orbital motion and spinning motion of electrons in atoms. Particularly ferromagnetism is mainly due to spin-spin interaction of unpaired electrons in the ferromagnetic atoms.

7.What are ferrites?

Ferrites are soft magnetic materials having the general formula $XFe_2 O_4$ where X is the divalent metal like Mn, Mg, Ni, Fe, etc. These are ferrimagnetic materials having different magnitude spin in the adjacent ions in the lattice. These have high resistivity and hysteresis loss at radio frequencies and hence these are used as transformer core materials at those frequencies.

8. What is mean by energy product of a hard magnetic material?

The product of residual magnetic induction (B_r) and coercively (H_c) is called energy product. It is the important quantity to design powerful permanent magnets. For example Alnico magnets have high energy products and hence they are very powerful permanent magnets.

9. For making electromagnet what is nature of magnetic material.

For making electromagnets we require high initial permeability, low coercivity and low hysteresis loss magnetic materials.
Example: Permalloy

10. What are ferrox cubes?

Ferrox cubes are the soft magnetic materials having narrow rectangular hysteresis loops. These are used in computer memories.
Example: Magnesium – manganese ferrite.

11.What are garnets?

Garnets are soft magnetic materials having high resistivity, low hysteresis loss and low current losses. These are used at microwave frequencies as non-reciprocal microwave devices like gyrator, isolator, etc. and as magnetic bubbie storage materials.
Example: Yttrium Iron garnet ($Y_3 Fe_5 O_{12}$).

12.What are ESD magnets? What are they properties?

ESD magnets are elongated simple domain magnets. These have very fine particles with larger magnetization. These are stable towards their magnetic properties and have a single domain structure.

13.How do you get high-energy product in a hard magnetic material?

Making irreversible domain wall movement by introducing voids or internal stresses inside the magnetic material, one can make hard magnetic material used for making powerful permanent magnets.

14. What are domains?

Domains are the small regions in a ferromagnetic material, which are completely magnetized by favourable exchange spin-spin interaction. The domains are responsible for large magnetization of ferromagnetic materials with very weak magnetic fields.

15.What is Meissner effect in superconductors?

Meissner effect refers to the complete exclusion of magnetic flux inside the superconductor when it is placed in a uniform magnetic field. Thus it indicates that superconductors are perfect diamagnetic.

16. What are the different types of superconductors?

Based on critical temperature, there are type I superconductor (soft superconductor) having complete Meissner effect or only one critical magnetic field (Examples: Al, Zn, Ga) and type II superconductor (hard superconductor) having incomplete Meissner effect or two critical magnetic fields between which the material is in the mixed state. (Example: Zr, Nb). Further there are p-type superconductors or high temperature superconductors in which charge carries are holes and n-type superconductors or low temperature superconductors in which charge carries electrons.

17. Mention few applications of superconductors.

i. Superconducting transmission system is used for transmission of electric energy with very low transmission loss.
ii. Superconducting magnets are used for producing very large magnetic field and for magnetic levitation.
iii. Cryotrons superconducting gating circuits act as switching elements in computers.
iv. Using superconducting components one can design an extremely fast and large scale computer occupying lesser volume and consuming electrical electrical energy less than ½ watt.

18. Explain the term superconductor.

Superconductor is the material having nearly zero resistivity and perfect diamagnetism. Thus a superconductor can conduct electric current without any resistance and excludes the magnetic flux from the material when it is placed in a magnetic field.

19. What is meant by superconducting transition temperature?

Superconducting transition temperature is the temperature at which normal material is converted into superconducting one when we cool the material.

20. What is D.C Josephson effect?

When two superconducting blocks of different materials like aluminum and tin are kept at liquid helium temperature and separated by a small gap of the order of few A° and are connected externally by a wire, a direct current flows in the external circuit. This is called D.C Josephson effect.

21. How will you design a microwave oscillator using superconductors?

When two superconducting blocks of same material like aluminum are kept at liquid helium temperature and separated by a small gap of order of few Å or a thin insulating layer and are connected to a D.C power supply, microwaves emanate from the gap or junction. Since a.c. microwaves are produced, this effect is called A.C.Josephson effect.

22. What is the effect of magnetic field on a superconductor?

When a superconductor is in the superconducting state and the applied magnetic field is greater than the critical, the magnetic flux enters in to the material and it becomes normal material. The critical field H_c depends on the temperature of the superconducting material such that $H_c = H_0 [1 – T^2 / T^2_c]$ where H_o = critical field at 0 K and T_c is the superconducting transition temperature.

23. What is a cryotron?

Cryotron is a switching element made from two different superconductors arranged in a manner that one superconductor in the form of a straight wire is enclosed by another superconducting coil and is based on the disappearance of superconducting state in a superconductor due to the production of magnetic field by the other superconductor surrounding the first superconductor.

24. How will you explain the phenomenon of superconductivity?

High temperature superconductivity can be explained by resonance valence bond theory such that attractive correlation brings intense electron pairing similar to that responsible for bonding hydrogen atoms in a hydrogen molecule. Low temperature superconductivity explained by BCS theory such that superconductivity is due to cooper pairs of electrons having opposite spins. At very low temperatures, cooper pair is formed through electron-electron interaction via lattice deformation.

25. What are critical temperature, critical magnetic field and critical current in the case of superconductivity?

Critical temperature 'T_c' is the temperature below, which the material behaves as superconductor.

Critical magnetic field 'H_c' is the minimum value of the magnetic field required to destroy superconductivity existing in the material at a temperature below its critical temperature.

$H_c = H_o [1 – (T / T_c)^2]$

Critical current 'I_c' is the minimum current required to destroy superconductivity existing in the material at a temperature below its critical temperature.

26. What are SQUIDS? What are their uses?

Superconducting Quantum Interference Devices (SQUIDS) are based on the flux quantization in a superconducting ring and is a double junction quantum interferometer formed from two Josephson junctions mounted on a superconducting ring. SQUID sensors have high sensitivity at low temperatures and are used to detect defects in heart and brain through magnetocardiography and magnetoencephalography.

UNIT – IV DIELECTRIC MATERIALS
PART – A

1. What is meant by dielectric breakdown?

Dielectric breakdown is the failure of the material at which the dielectric loses its insulation resistance and permits large currents to pass through it.

2.What are the dielectrics?

Dielectrics are the materials having permanent electric dipoles or having the ability to produce enormous induced dipoles in the presence of applied electric field.

3. Explain the important properties associated with the dielectrics.

i. Ferro electricity: Property by which dielectric materials exhibit electric polarization even in the absence of applied electric field.
ii. Piezo electricity: Property by which electric polarization is produced by mechanical Pressure.
iii. Pyroelectricity: Property by which electric polarization is produced by thermal energy.

16. What is meant by local field in a dielectric?

The local field in a dielectric is the space and time average of the electric field acting on a molecule or atom of the dielectric kept in an applied electric field. It is equal to

$E_i = E + P/3\varepsilon_0$ for simple elements dielectricals.

Here, E = applied field strength and
P = polarization field produced in the dielectric.

17. Define dielectric loss.

When a dielectric is subjected to the a.c. voltage the electrical is absorbed by the material and is dissipated in the form of heat. This dissipation of energy is called dielectric loss. The dielectric loss is mainly due to imaginary term of the complex dielectric constant.

18. Define dielectric constant.

Dielectric constant is the measure of the polarization in a material. It is also called relative permitivity 'ε_r' of the material.

Thus, $\varepsilon_r = E_o \backslash E_o - E_p$

Where E_o = applied electric field.
E_p = produced polarization field.

If there is more polarization in a medium then E_p is more and ε_r is higher for that medium.

19. Define electric polarization.

Electric polarization means production or inducement of electric dipoles by the applied electric field. It is due to shifting of the charges in the material by the applied electric field. It depends upon frequency of the applied field and temperature.

20. Define dielectric polarization.

Dielectric strength is the minimum voltage required per unit thickness of the material to produce dielectric breakdown or dielectric failure. Unit: V / m

21. Mention three important liquid dielectric materials.

i. Transformer oil
ii. Askarels
iii. Silicon liquid

22. What are dielectrics, ferroelectrics, piezoelectrics and pyroelectrics?

Dielectrics - materials having electric dipole moment permanently or temporarily by the applied electric field.
Ferroelectrics – materials having electric dipole moment at the atomic or molecular level even without the applied electric field.
Piezoelectrics – materials which produces electrical voltage when there is a perpendicular mechanical stress.
Pyroelectrics – materials which are polarized by the absorption of thermal energy.

UNIT – V ADVANCED ENGINEERING MATERIALS

PART – A

1. What are metallic glasses?

Metallic glasses have the properties of metals and glasses such that they have ductility, malleability and brittleness. Ferromagnetic metallic glasses are in the form of ribbons and are used as light weight magnetic cores having no losses.

2. What are shape memory alloys?

Shape memory alloys or SMART materials or intelligent materials are the materials which respond with a change in shape on the application of mechanical stress along with the application of thermal or magnetic fields.

3. What are the applications of SMA's?

SMA's can act as actuators and sensors. Textile materials like SMA T-shirt can detect a variety of signals from the human body and weather conditions so as to allow from greater comfort. Fiber composite SMAs are used to produce twist on the helicopter blades. It is used in orthopaedic devices for pulling fractures together, artificial hearts and shrink-wrap.

4. Define Nanotechnology?

Nanotechnology is the engineering of functional systems at the molecular scale and fabrication of devices within that size range. It is the study and use of structures between 1 nanometer and 100 nanometers in size.

5. What is meant by bottom-up approach in constructing Nanomaterials?

In the "bottom up" approach, materials and devices are built from molecular components which assemble themselves chemically by principles of molecular recognition. These seek to arrange smaller components into more complex assemblies.

6. What is meant by top-down approach in constructing Nanomaterials?

In the "top-down" approach,nano-objects are constructed from larger entities without atomic-level control. These seek to create smaller devices by using larger ones to direct their assembly.

7. What are non linear optical materials?

For very large intensities of light, as in lasers, it is observed that the refractive index of optical materials, frequency change with intensity and two photons interact with each other which makes it possible to control light by using light. The superposition principle is not obeyed at such intensities. This behavior of light at large intensities is known as non linear behavior and the materials exhibiting this behavior are known as non linear optical materials.

8. What is optical Kerr effect?

The change in refractive index of a material by light of large intensity is known as optical Kerr effect or AC Kerr effect.

9. What is second harmonic generation?

The presence of radiation of twice the frequency(or half the wavelength) of incident light in the re-radiated light in a non linear medium is known as second harmonic generation.

10. What is self focusing in NLO materials?

The variation in intensity along the cross section of the beam causes the refractive index to vary along the cross section due to variation in the non linear effect. This causes the beam to focus without the use of lenses.

11. What are biomaterials?

Materials which are used as replacements for damaged human body parts like the hip joint, knee joint, teeth etc, are known as biomaterials.

12. Mention few biomaterials and their applications.

a) Stainless steels(ASTMF-138 AND ASTMF-139) have high tensile strength and high biocompatibility and are used as steel wires, plates and implant devices.
b)Porous high density polyethylene is used in dental and cortical implants.
c) Ceramic implants (Al_2O_3 with SiO_2 and alkali metal oxide) are used to make femoral head.